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U. S. Bureau of Animal Industry.

Chemical Testing of milk & Cream,

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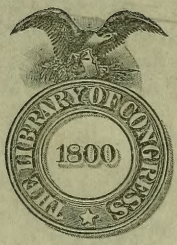

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.

CHEMICAL TESTING OF MILK AND CREAM

BY

ROSCOE H. SHAW,
Chemist, Dairy Division.

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A. D. MELVIN, Chief.

CHEMICAL TESTING OF MILK AND CREAM.[1]

By ROSCOE H. SHAW, *Chemist, Dairy Division.*

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CHEMICAL NATURE OF MILK.

In order to follow intelligently the methods for testing milk and cream some knowledge of the chemistry of milk is essential. From a chemical standpoint milk is a very complex substance. The component parts may, however,

[1] In preparing this bulletin free use has been made of the various publications on the subject, particularly "Testing Milk and Its Products," by Farrington, E. H., and Woll, F. W. (Madison, Wis., 1911), and "Modern Methods of Testing Milk and Its Products," by L. L. Van Slyke (New York, 1907).

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be classified into a few well-marked groups, as follows: (1) Water, (2) fat, (3) nitrogenous constituents, (4) sugar, and (5) ash. The components other than water are collectively known as total solids or milk solids, and the solids other than fat as solids not fat. Milk serum, or more properly milk plasma, is the term used to denote the milk minus the fat; hence the terms serum solids and plasma solids are synonymous with solids not fat.

Water.—The water in milk varies from 82 to 90 per cent. The usual variation in mixed-herd milk is much less and is probably covered by 84 to 88 per cent.

Fat.—The fat in milk—milk fat or butter fat—is not in solution but exists as an emulsion of microscopic globules so small that a single drop of average milk contains more than one hundred millions of them. These globules, even in milk from one cow, are not all of the same size. Some may be two or three times the size of others, the average size depending upon several factors, the principal one of which is the breed of the animal. Chemically the fat is not a single compound but a mixture of several compounds known as glycerids. Some of these glycerids are common to all fats, while others are peculiar to butter. This fact is made use of in detecting oleomargarin or artificial butter.

Cows' milk usually contains from 3 to 6 per cent of fat, depending very largely upon the breed of the animal.

Nitrogenous constituents.—These are principally casein and albumin, with traces of less important nitrogenous compounds. The coagulum produced by rennet, dilute acids, or certain other chemicals, when added to milk, is chiefly casein. Albumin is the flocculent precipitate produced by heating whey or skimmed milk from which the casein has been removed. In constitution and behavior it closely resembles white of egg. Casein is not really in solution in the milk, but exists in an extremely fine colloidal condition in combination with some of the ash constituents. With an appropriate filter of clay it is possible to separate it from the water. Albumin is in true solution in the water of the milk. Frequently, but improperly, the term casein is applied to all the nitrogenous constituents in milk. Sometimes the term total proteins is used in referring to the nitrogenous constituents

taken as a whole. The amount of casein in average cows' milk varies from 2 to 4 per cent and the albumin from 0.5 to 0.8 per cent.

Sugar.—Milk sugar, or lactose, belongs to a group known as carbohydrates, and is a white substance less sweet in taste than cane sugar. Milk sugar is broken up into lactic acid by the action of bacteria, this bringing about the souring of milk. Milk sugar is in solution in the water of the milk and is present to the extent of from 3.5 to 6 per cent.

Ash.—The ash, or the mineral part of milk, exists to the amount of about 0.75 per cent and consists largely of the chlorids and phosphates of sodium, potassium, magnesium, and calcium.

AVERAGE CHEMICAL COMPOSITION.

The table below gives the average of more than 5,000 analyses of milk at the New York State Agricultural Experiment Station, Geneva:

	Per cent.
Water	87.1
Total solids	12.9
Fat	3.9
Casein	2.5
Albumin	.7
Sugar	5.1
Ash	.7

TESTING FOR FAT.

In the following remarks on the testing of milk and cream the aim will be to present the subject in such a manner that it may be followed by those who have had neither chemical training nor a course of any sort in milk testing. To those who have had such training the following pages will doubtless appear very elementary and overburdened with detail.

TESTING MILK FOR FAT.

Preparing the sample for testing.—As before mentioned, fat is not in solution in milk, but is in an emulsion of very fine globules. These, being lighter than the surrounding serum, tend to rise, carrying with them some of the other solids, resulting in the familiar creaming of milk. Before

the test can be made a homogeneous mixture must be obtained. This can best be obtained by pouring the milk several times from one vessel into another. When the sample is small, beakers are convenient for this purpose, and if the sample has not remained in the container more than a few hours, pouring back and forth four or five times is sufficient. When, however, the sample has stood for some time in the container, the cream layer is liable to be hard and to adhere to the walls. This is particularly true of preserved samples. In such event it is well to place the container in warm water until the cream has become softened and can then be easily removed. Care must be taken that none of the cream is left on the cover of the container; if, however, any is left, a brush such as is used in cleaning beakers is useful in dislodging it.

The sample must always be well mixed immediately before measuring out a charge for testing. If several charges are to be measured out, the sample must be mixed each time. Thorough mixing is imperative for accurate work.

Partially churned milk.—Milk from some cows, notably of the Jersey breed, churns very easily and sometimes a too vigorous agitation in the mixing of such milk results in some of the fat collecting in small granules which refuse to emulsify again. This also frequently happens when the milk is sent a long distance in partially filled containers. These granules are easily recognized, and when they are present special treatment is required to prepare the sample for testing. A little ether equal in volume to 5 per cent of the milk may be added, and the container stoppered and vigorously shaken. The ether will dissolve the granules and the solution will mix with the milk. A fairly accurate charge may now be quickly removed, but the percentage obtained must be corrected for the volume occupied by the ether.

Another and perhaps a better way to treat churned milk is to place the container in hot water until the milk has attained a temperature of about 110° F. In a few minutes at this temperature the granules will have melted. The container is then vigorously agitated and a charge for test immediately measured out.

The partial churning of the sample is not a frequent occurrence and with proper care can always be avoided. When samples are to be sent a considerable distance the containers should be completely filled so that no space is left at the top. A good way is to fill a bottle to overflowing with the mixed sample and then to insert a rubber or cork stopper having a hole about one-eighth of an inch in diameter. As the stopper goes to its place the milk will spurt out through the hole; the hole is then filled with a piece of glass rod or a wooden plug. When treated in such a manner milk will not churn.

Sour milk.—While the souring of milk does not affect the fat, it is impossible to obtain a representative charge from curdled milk without special treatment. In order to obtain a good mixture it is necessary to dissolve the curd. This may be accomplished by adding 5 or 10 per cent by volume of a strong solution of either caustic soda or potash; strong ammonia water may also be used. The alkali must be thoroughly mixed with the milk until it is completely liquid. The charge for test must be immediately measured out and a correction made in the final percentage for the volume occupied by the alkali solution. If desired, the powdered alkali may be added directly to the milk in small portions at a time, being sure that one portion is dissolved before another is added, and agitating until the milk has become liquid. No correction is necessary for the volume occupied by the powdered lye. When making a fat test on milk containing alkali, special precautions must be observed in adding the sulphuric acid, as an excessive amount of heat is generated and the contents of the test bottle may be thrown out. When alkali is used, slightly more acid is required.

THE BABCOCK TEST.

The Babcock test for fat in dairy products, named for its inventor, Dr. S. M. Babcock, chief chemist of the Wisconsin agricultural experiment station, is based upon the fact that strong sulphuric acid will dissolve the serum solids in milk and set the fat free from its emulsion. In conducting the test, the charge is placed in a specially constructed test bottle and mixed with the proper quan-

tity of sulphuric acid. The acid performs other functions than the simple solution of the serum solids. Much heat is developed by its action, and this causes the fat globules to lose their individuality and run together, a condition which greatly facilitates the separation from the serum, and this separation is still further accelerated by the increase in specific gravity of the serum caused by the

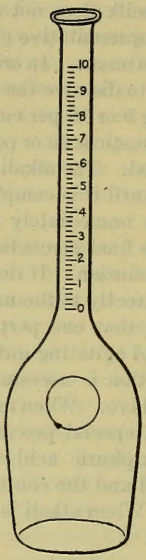

FIG. 1.—Old type of Babcock milk-test bottle.

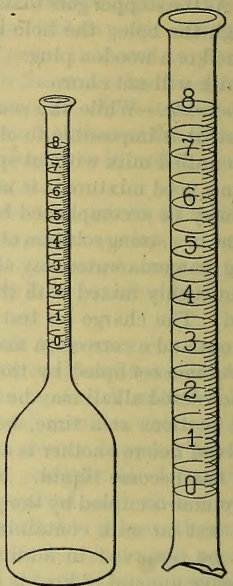

FIG. 2.—Type of Babcock milk-test bottle conforming to the requirements of the United States Bureau of Standards, and showing graduations.

presence of the heavy sulphuric acid. When the solution of the serum solids is effected the complete separation of the fat and serum is accomplished by whirling in a centrifuge. The fat is gradually driven into the graduated neck of the bottle and the percentage read directly.

Test bottles.—The Babcock-test bottle for milk, as shown in figure 1, consists of a body holding about 50 cubic centi-

meters and the neck graduated so that the percentage of fat may be read directly. Seventeen and one-half cubic centimeters are used in the test, and this volume of average milk weighs almost exactly 18 grams. At the temperature at which the bottles are standardized the specific gravity of butter fat is about 0.9. Two cubic centimeters weigh twice 0.9, or 1.8 grams, which is just one-tenth of the weight of the charge used in the test bottle. The volume between 0 and 10 per cent in the neck should, therefore, be 2 cubic centimeters, if the bottle has been correctly standardized. Each unit per cent is represented by a volume of 0.2 cubic centimeters in the neck. The old types of bottles were 10 per cent bottles, the smallest subdivision being 0.2 per cent. In the more recent types, notably those made to conform to the specifications of the United States Bureau of Standards, the necks are somewhat smaller in diameter and read only to 8 per cent, and the smallest subdivision is 0.1 per cent. (Fig. 2.)

FIG. 3.—Pipette holding 17.6 cubic centimeters, used in measuring milk in the Babcock test.

Milk pipette.—The charge for the Babcock test for milk is measured rather than weighed, the measuring instrument being a pipette graduated to deliver 17.5 cubic centimeters of milk. These pipettes, filled to their graduation mark, hold 17.6 cubic centimeters. The extra 0.1 cubic centimeter is allowed for the milk which clings to the walls. Pipettes may be obtained which conform to the requirements of the United States Bureau of Standards. (Fig. 3.)

Acid measure.—This may be either a simple glass cylinder graduated to deliver 17.5 cubic centimeters, or one of the more complicated devices shown in figures 4, 5, and 6. A convenient little device is the small beaker with the glass handle by which the proper quantity of acid may be

dipped out of a larger beaker and poured into the test bottle. (See fig. 7.)

The centrifugal machine.—This is commonly called the Babcock tester, and various types are on the market, ranging from the small, two-bottle hand tester to the large steam turbine or electric tester, accommodating 24 or more bottles. (See figs. 8, 9, 10, and 11.) They all consist mainly of a horizontal revolving disk or wheel provided with swinging sockets to hold the bottles. At rest, these

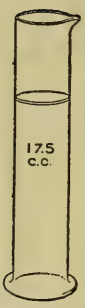

FIG. 4.—Simple acid graduate.

FIG. 5—Burette for measuring the acid.

FIG. 6.—A combined bottle and acid measure.

sockets allow the bottles to stand upright, but when in motion, the centrifugal force causes the sockets to swing outward, bringing the bottles to a horizontal position, with the necks toward the center. Where steam pressure is available, a steam-turbine tester is strongly recommended for the reason that it maintains a uniform motion under a definite pressure and at the same time the steam keeps the bottles warm and supplies the hot water required. Whatever kind of tester is used, it must be firmly secured

to a rigid support. There must be no shaking or trembling of the tester when in motion.

Acid.—The acid used in the Babcock test is the commercial sulphuric acid, sometimes called oil of vitriol, and should have a specific gravity of between 1.82 and 1.83. It should be kept in glass bottles or jugs, preferably with glass stoppers. Rubber stoppers will last for a time, but

FIG. 7.—A dipper made entirely of glass and holding 17.5 cubic centimeters for measuring acid in the Babcock test.

the use of cork stoppers is not permissible, as cork is rapidly attacked by the acid. Owing to the property of sulphuric acid of absorbing water from the air and thus diluting itself, it can not be kept in open containers.

Sulphuric acid is an extremely corrosive liquid, which attacks the skin, the clothing, wood, and most of the com-

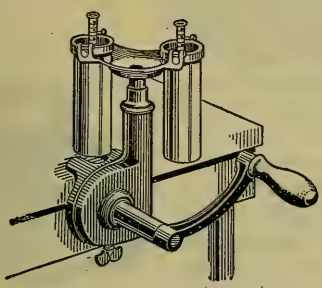

FIG. 8.—A 2-bottle hand tester.

mon metals. Should the acid be spilled on the clothing, it should be immediately washed off with plenty of water, and ammonia water applied; this in turn must also be washed off. Unless the acid is washed off immediately after contact with the skin, severe burns will result. Acid spilled on the table or floor may be neutralized with washing soda or other alkali. Lead is the only common metal

not attacked by this acid. If much testing is to be done, it is a good plan to cover the testing table with sheet lead.

Testing strength of acid.—As already mentioned, the specific gravity of the sulphuric acid used should be between 1.82 and 1.83. It is much better to purchase it guaranteed of the proper strength than to bother with diluting the stronger acid. Creamery supply houses handle acid guaranteed to be of the proper strength, and if kept in well-stoppered containers it will not change. For the benefit of those who prefer to test the acid themselves, the following directions are given:

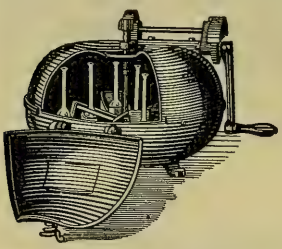

FIG. 9.—A hand tester for 12 bottles.

Use of the acid hydrometer.—This is a hydrometer designed only for liquids having a specific gravity about that of concentrated sulphuric acid. (See fig. 12.) It is standardized at 60° F., and for correct results must be used with acid at that temperature only. The acid at this temperature is poured into the hydrometer cylinder and the hydrometer allowed to float in it. When it has come to rest, the point on the scale intercepting the surface of the acid indicates the specific gravity. If it is much under 1.82 it can not be used for testing milk, and should be discarded and a fresh lot of acid obtained. If it is above 1.83 it may be diluted with water until it is of the proper strength. There are two ways of doing this. The acid may be exposed to the air until it absorbs sufficient water to lower its specific gravity; this is

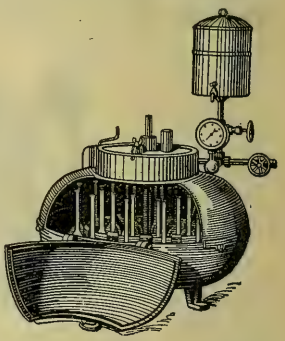

FIG. 10.—A type of steam tester with an arrangement for heating the water used in the test.

the safest and best way if the specific gravity of the acid is not much above the standard. The second way is to mix the acid with a small quantity of water. A small quantity of water is placed in a bottle or jar and the acid poured into it. Never pour water into acid, as a serious accident may result. After the mixture has cooled to 60° F. it is again tested with the hydrometer and the process repeated if necessary.

DIRECTIONS FOR MAKING THE BABCOCK TEST WITH MILK.

Measuring the charge.—Directions have already been given for preparing the sample for the test. The milk is poured from one beaker to another two or three times. The tip of the pipette is immediately inserted and the milk sucked up with the mouth until it reaches a point well above the graduation mark on the stem; the dry forefinger is then quickly placed over the mouth of the pipette. By slightly relaxing the pressure of the finger the milk is allowed to flow down until it just reaches the mark. The tip of the pipette is now placed in the neck of the test bottle and the milk allowed to flow slowly down the side. The right way is to hold the pipette obliquely to the mouth of the test bottle as shown in figure 13. The wrong way is shown in figure 14. If the bottle and pipette are held in the latter position the neck of the bottle may clog up and some of the milk run over the top. Care must be taken that none of the milk is lost during the operation. When nearly all the milk has run out of the pipette, the last drop is forced out with a puff of the breath.

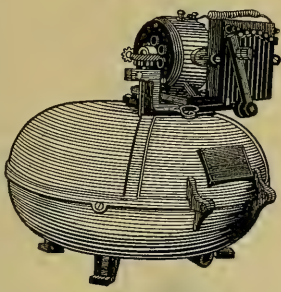

FIG. 11.—A type of electric tester.

Adding the acid.—The temperature of the milk when the acid is added should be between 60° and 70° F., and the acid should be at about the same temperature. Seven-

teen and one-half cubic centimeters of the acid are measured out, and, with the bottle held at an angle, carefully poured down the side, the bottle being turned slowly at the same time so that any milk adhering to the neck will be washed down. For two reasons the acid must not be poured into the middle of the test bottle; first, because it may form a plug in the neck, which may be driven out by the expansion of the air below; and second, because the

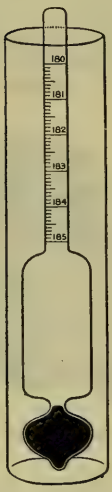

FIG. 12.—Hydrometer and cylinder used in testing sulphuric acid.

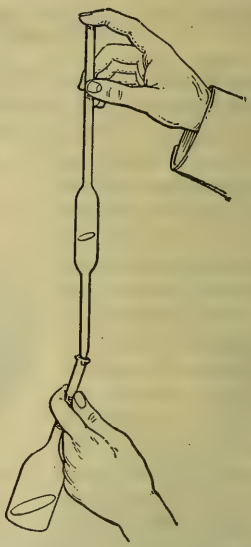

FIG. 13.—The right way of adding milk to the test bottle. (Farrington and Woll, Testing Milk and Its Products.)

acid may partially mix with the milk and produce black particles which do not dissolve and later interfere with the reading of the test. The acid and milk should now be in two distinct layers without much of a dark layer between them.

Mixing the acid and the milk.—The acid is now mixed with the milk by giving a combined rotary motion and gentle shaking with the hand grasping the neck of the

bottle. When once commenced the mixing must not be interrupted until the solution is complete. The first effect of the acid on the milk is a curdling, which is subsequently dissolved. As the solution progresses the color changes first to a light yellow, then to dark yellow, then through various shades of violet to brown and finally to dark brown, if the acid is of the proper strength and the milk and acid are at the right temperature when united. Too strong or too warm acid produces a dense black. If the milk has been preserved with formaldehyde, a longer time is required to complete the solution, owing to the toughening of the casein by that preservative. Common errors of beginners are failure to mix the acid thoroughly with the milk and to continue the shaking until the solution is complete. A good plan is to shake the bottle for a minute or so after the solution is apparently complete. Although not necessary, it is preferable to centrifuge the bottles immediately, though they may be kept 24 hours if desired, in which case they must be placed in water from 170° to 180° F. for 15 to 20 minutes before whirling.

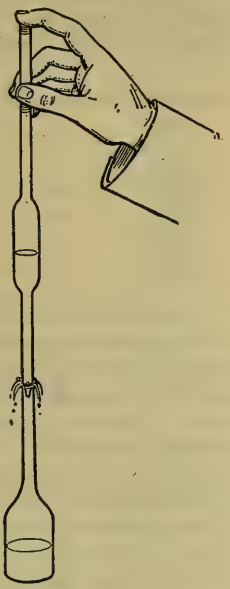

FIG. 14.—The wrong way of adding the milk to the milk bottle. (Farrington and Woll, Testing Milk and Its Products.)

Centrifuging the bottles.—The bottles are now placed in the sockets of the centrifuge, taking care that they are equally distributed about the wheel or disk so that the equilibrium of the latter is not disturbed. An even number of bottles should always be whirled. Should an odd number of tests be made a test bottle filled with water may be used to balance the machine. When the bottles are in place, the tester is covered in order to keep the bottles

from getting cold and to protect the operator from flying glass and acid should any of the bottles break. The tester is now set in motion and the bottles whirled 4 to 5 minutes at the proper speed. This will be sufficient to bring practically all the fat to the surface. In cold weather, if a hand tester is used, it may be necessary to pour hot water into the jacket of the tester to keep the bottles warm.

Speed of centrifuge.—Farrington and Woll have calculated the proper speed of testers with wheels of different diameters to be as follows:

Diameter of wheel in inches:	Revolutions of wheel per minute.
10	1,074
12	980
14	909
16	848
18	800
20	759
22	724
24	693

Adding the water.—With the pipette or with the device for the purpose attached to some steam testers, or in any other convenient manner, hot water is added to the bottles until the contents come nearly to the lower part of the neck. The cover is now replaced on the tester and the whirling repeated for one minute. Hot water is again added until the fat reaches a point below the highest graduation mark on the neck. It must never reach the top mark, or some of the fat may be lost. This time the water should be dropped directly into the fat in order to clear the fat of the light, flocculent material which may be entangled in it and which would later interfere with the reading of the test. The whirling is repeated for another minute. The temperature at which the readings are taken is between 130° and 140° F., and this should be borne in mind when the water is added, the object being to add the water at such a temperature that the temperature of the fat at the close of the last whirling will be between these two figures.

The water used should preferably be soft water or condensed steam. The use of hard water is liable to cause trouble on account of its carbonates; these are decomposed by the acid, liberating carbon dioxid, which may cause

foam on the top of the fat column and obscure the meniscus. If soft water or condensed steam is not available, hard water may be used if, before heating it, a few drops of sulphuric acid are added.

Reading the percentage.—If the test has been successfully conducted, the fat will be in a clear, yellowish liquid column sharply separated from the clear and nearly colorless acid solution immediately below it and with no foam on top. The bottles should be kept warm either in the tester or in warm water until read, and the readings should always be made at between 130° and 140° F. The fat at this temperature will, if other conditions have been correct, have a well-defined meniscus at both the top and the bottom. The readings are made from the extreme bottom of the lower meniscus to the extreme top of the upper meniscus. Figure 15 shows this graphically. An ordinary pair of dividers is useful in making this reading. The points are placed at the upper and lower limits, then lowered until one point is at the 0 mark; the other point will intercept the scale at the correct percentage for the sample tested.

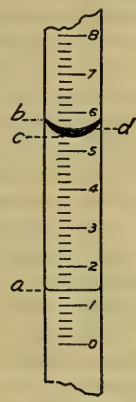

FIG. 15.—Showing method of reading fat column in milk testing. Read from *a* to *b*, not *a* to *c*, nor *a* to *d*.

In some steam testers where the exhaust steam escapes into the jacket and no ventilation is provided, the temperature of the bottles will be too high. In such case, the bottles must be allowed to cool to 130° to 140° F. by placing them in water at that temperature for several minutes before making the reading.

Imperfect tests.—If the foregoing directions have been strictly followed, a perfect test should result. It is not to be expected, however, that the beginner will always meet with success. The next two paragraphs may be helpful in locating the trouble.

An imperfect test is caused by one of three things: (1) Foam on the fat column obscuring the upper meniscus; (2) a dark-colored fat column containing dark particles and with dark particles obscuring the lower meniscus;

(3) a light-colored fat column containing white, caseous material obscuring the lower meniscus.

The first is caused by using hard water. Any one or a combination of the following may cause the second trouble: (*a*) The acid was too strong; (*b*) too much acid was used; (*c*) the acid was too warm when added to the milk; (*d*) the milk was too warm when the acid was added; (*e*) the acid was dropped directly into the milk; (*f*) the mixing of the acid and the milk was interrupted before the solution was complete; or (*g*) the acid and milk were allowed to stand too long in the test bottle before being mixed. The third trouble is caused by one or more of the following: (*a*) The acid was too weak; (*b*) too little acid was used; (*c*) the acid was too cold when added to the milk; (*d*) the milk was too cold when the acid was added; or (*e*) the mixing was not continued long enough to dissolve all the serum solids.

Tested Babcock glassware.—Babcock-test bottles and pipettes should always be tested and found correct before being used. It is now possible to purchase test bottles and pipettes which have been tested and approved by the United States Bureau of Standards. Many States also have officials empowered to test and approve Babcock glassware. The best way is to purchase it already tested by the Bureau of Standards, or to have it made to conform to the requirements of that bureau and then tested by a State official.

TESTING CREAM FOR FAT.

While in a general way cream is tested by the Babcock test in much the same manner as milk, there are some modifications that must be observed. The range of fat in cream, and consequently the specific gravity is much greater than in milk, so that 17.5 cubic centimeters do not necessarily represent 18 grams, as in the case of milk. Cream also varies in consistency, some being thin and some thick; therefore in some cases much more would adhere to the walls of the pipette than in others. For these reasons cream can not be accurately measured. The charge for the test must be weighed into the test bottle.

Cream-test bottles.—The cream-test bottles used in the Babcock test are of various designs, as shown in figures 16, 17, 18, and 19. Those conforming to the requirements of

the United States Bureau of Standards differ from milk bottles only in the graduations and in the length and diameter of the neck. Test bottles are made for both an 18-gram and a 9-gram charge.

Cream-test balances.—Several types of balances designed for weighing cream charges are on the market (figs. 20, 21, and 22). The small torsion balances prove to be very satisfactory if care is taken that the important metal parts

FIG. 16.—9-gram, 6-inch cream bottle.

FIG. 17.—18-gram 6-inch cream bottle.

are not allowed to rust. Balances should be tested for sensitiveness from time to time and should always be kept in perfect condition.

Preparing cream for testing.—The point never to be lost sight of in testing cream or milk is that the small quantity taken for the test must be truly representative. No matter how carefully the test is carried out, if the charge taken does not accurately represent the cream or milk to be

tested, the results will be worthless. The preparation of cream for testing does not differ materially from that of milk. The fat must be evenly distributed, and if there are no lumps this can be accomplished by pouring from one receptacle to another, warming the cream slightly if cold. If lumps are present, it has been advised to pass the cream through a fine sieve, rubbing the lumps through with the fingers and then mixing as usual. If the cream has stood for some time in the sample jar, the top may have become hard, leathery, and difficult to remove. In this case, the jars should be set in warm water until the contents have reached 100° to 110° F., when the cream will be soft and can be easily removed.

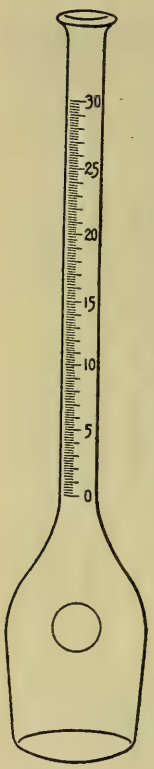

FIG. 18.—18-gram 9-inch cream bottle.

Weighing the charge.—After the sample has become homogeneous throughout, the charge is quickly weighed into the test bottle. The weight of the charge depends upon the style of bottle used. For this purpose the 9-gram bottle is recommended. A pipette is useful in conveying the cream to the test bottle, as the flow can be easily controlled and checked on the drop when the pointer of the balance indicates that the correct quantity has been run in. This weight must be exact, and some experience is necessary before the charges can be quickly and accurately weighed.

Completing the test.—Instead of adding a measured quantity of sulphuric acid to the cream in the test bottle, as is done with milk, the best way is to add the acid until the mixture assumes the color of coffee to which cream has been added.[1] The quantity of acid required to produce this color varies with the percentage of fat in the cream. If the cream and acid when mixed are about 70° F., from

[1] O. F. Hunziker and H. C. Mills, Testing Cream for Butter Fat, Indiana Agricultural Experiment Station, Bul. 145. June, 1910.

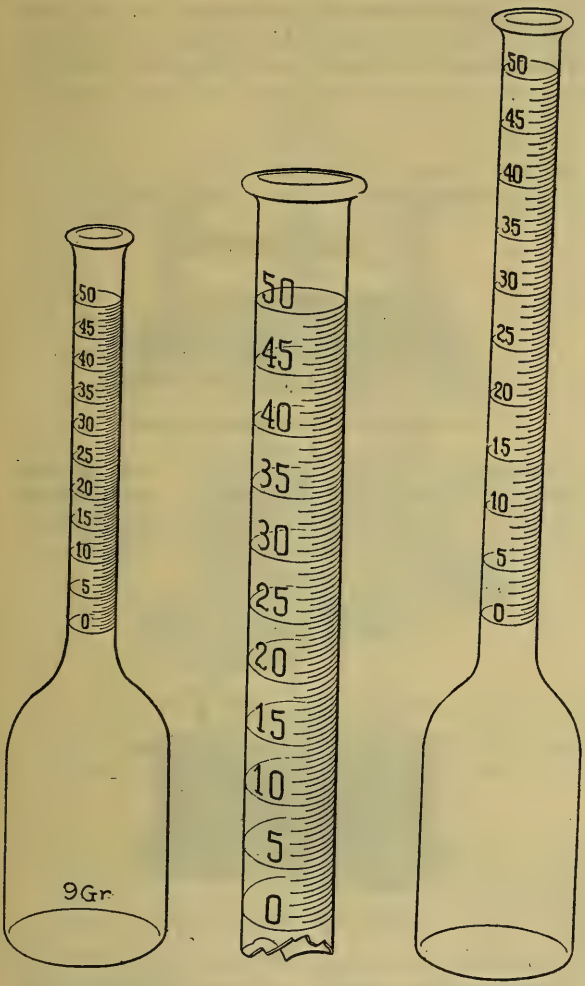

FIG. 19.—Types of cream bottles conforming to the requirements of the United States Bureau of Standards.

4 to 8 cubic centimeters of acid (specific gravity 1.82 to 1.83), depending upon the percentage of fat, will be required for a 9-gram charge. After adding the acid to the cream, the procedure up to the reading of the percentage

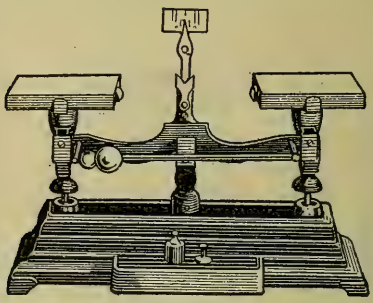

FIG. 20.—Type of knife-edge cream balance.

is exactly the same as in the milk test. After the final whirling, the test bottles are submerged to a point above the fat column in water at 135° to 140° F. in a suitable tank. After remaining in this tank for about 15 minutes they are

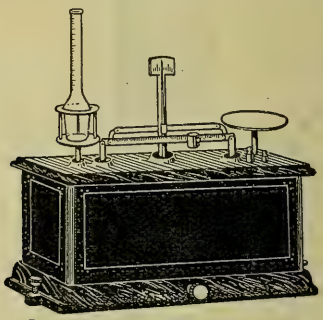

FIG. 21.—Type of torsion balance for single bottle.

removed and the readings quickly made. The important difference between reading the cream test and the milk test is that in the cream test the fat column included is from the bottom of the lower meniscus to the bottom, not the top, of the upper meniscus. (See fig. 23.) It is advised

to destroy the upper meniscus by dropping into the bottle at this point a few drops of a liquid in which the fat is not soluble. Glymol (petrolatum liquidum, U. S. P.), known commercially as white mineral oil, gives satisfactory results and may be purchased at almost any drug store. If desired it may be colored with alkanet root.[1] If glymol is used, the fat column included in the reading is from the bottom of the lower meniscus to the line between the fat and the glymol. If the fat column is read with the upper meniscus intact, care must be taken that the eye is on a

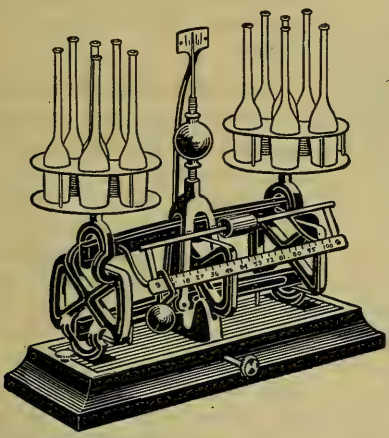

FIG. 22.—Type of torsion balance for several bottles.

level with the points on the scale at which the readings are made; otherwise an error will be introduced.

PRESERVING SAMPLES.

If, for any reason, it is desired to keep a sample of milk or cream for a few days before testing it, a preservative should be added to prevent decomposition. Formalin (which is a 40 per cent solution of formaldehyde), corrosive sublimate (mercuric chlorid), or potassium bichromate are used for this purpose. Formalin has the advantage of being a liquid and easily handled; on the other hand, it

[1] Hunziker and Mills, loc. cit.

has the property of toughening the casein and rendering it more difficult to dissolve later in the sulphuric acid. One cubic centimeter should keep a pint or a quart of milk or cream for two weeks or more. Corrosive sublimate, while the most powerful of the three, is a deadly poison. Samples preserved with it should be colored in some way to indicate the presence of the poison. Tablets of corrosive sublimate containing coloring matter are on the market. If potassium bichromate is used, the samples should be kept in a dark place; 15 to 20 grains is sufficient to preserve a pint for a reasonable length of time.

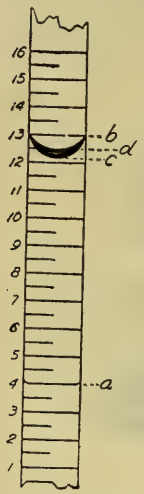

FIG. 23.—Showing method of reading fat column in cream testing. Read from *a* to *c*, not *a* to *b*, nor *a* to *d*.

CLEANING THE TEST BOTTLES.

After the test, and before the test bottles have become cold, they should be emptied with a shake or two to loosen the deposit of calcium sulphate which accumulates on the bottom. A convenient device is shown in figure 24. This consists of a 5-gallon stone jar with a wooden cover in which one-half-inch holes have been bored. After the test the necks of the bottles are placed in the holes and the contents allowed to run out, giving each bottle an occasional shake. The bottles should then be rinsed out twice with boiling water and, after the outside has been rinsed off, placed in a suitable rack and drained. At frequent intervals the bottles should also be given a bath in a dilute solution of lye, or a solution of soap or cleansing powder.

DETERMINATION OF TOTAL SOLIDS IN MILK.

As brought out earlier in this circular, milk is composed of water and the various solids collectively known as total solids or milk solids. Manifestly the simplest way of determining the amount of total solids in a given quantity of milk is to separate them from the water and weigh them.

This is precisely the manner in which the total solids in milk are determined in the laboratory. A small quantity of milk is weighed into a shallow, flat-bottomed dish, and then heated until all the water is driven off. During this evaporation the milk must not be heated more than a degree or so above the boiling point of water, because at a higher temperature some of the solids are decomposed.

Ovens.—Several types of ovens are used for holding the milk at the right temperature during the evaporation. The simplest type is perhaps the so-called double-walled drying oven (fig. 25). This piece of apparatus is really one oven inside of another, the space between the two being partly filled with water. A burner placed under the oven boils the water, and the remaining space between the walls is filled with steam, maintaining a constant temperature in the inner compartment which holds the milk dishes. Unless carefully watched, the oven will "boil dry," to prevent which it is a good plan to attach some sort of condenser. The type of condenser known as the globe condenser is very satisfactory for this purpose. Some ovens are constructed with a constant-level attachment.

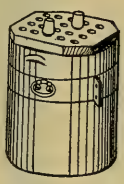

FIG. 24.—Jar with perforated cover for use in emptying test bottles.

Balance.—Nice weighings are required in the determination of total solids in milk, and it is necessary to use the type of balance known as the analytical balance (fig. 26), the cream-test balance not being sensitive enough for this purpose. On the other hand, the analytical balance can not be used with advantage in weighing cream charges. Both balances are required. An analytical balance sensitive enough for the purpose can be purchased for from $30 to $40. A set of accurate analytical weights will also be required. Space does not permit directions for using the analytical balance. If the operator is not familiar with its use, he is advised to consult some elementary treatise on quantitative chemical analysis. It must be borne in mind that the analytical balance is a very delicate instrument and should be treated accordingly.

Desiccators.—Dishes that are warm can not be accurately weighed on the balance because air currents are created which will buoy up the scale pan sufficiently to make the object appear lighter than it really is. Again, many substances can not be exposed to the air without absorbing atmospheric moisture and in this way introducing an error into the weighing. For these reasons it is customary always to cool the dishes in a device known as a desiccator (fig. 27) before weighing them. A desiccator is a specially

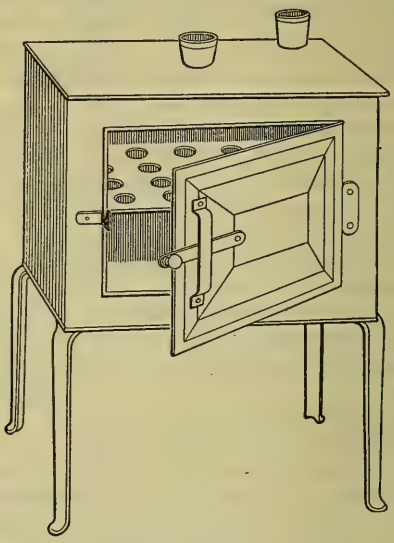

FIG. 25.—Double-walled drying oven.

constructed covered jar containing a substance like calcium chlorid, which attracts to itself all the atmospheric moisture in the inclosed space surrounding it. The desiccator, containing no moisture, will, of course, permit a substance to be kept in it without absorbing any. The calcium chlorid, which forms a layer about 1 inch deep on the bottom of the desiccator, should be renewed as soon as it shows any signs of moisture. The cover of the desiccator should be removed only as often as is necessary, and then for the shortest possible time.

Milk dishes.—These are best made of aluminum and should be from 2 to 2½ inches wide and about one-half inch deep (fig. 28). Each dish should bear a number by which

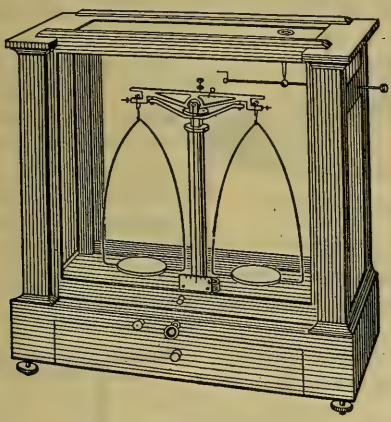

FIG. 26.—Analytical balance.

it can be identified; this number may be scratched or punched on the side.

Preparing the dishes.—After the dishes are clean and dry they should be placed in the drying oven for half an hour, then removed and placed in the desiccator until cool. They should be handled with forceps or crucible tongs, and as soon as they are cool they are weighed on the analytical balance.

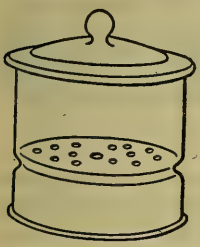

FIG. 27.—Desiccator.

Weighing the charge.—After the milk has been thoroughly mixed, it is drawn up in a pipette and allowed to flow into the dish until a thin film just covers the bottom; the dish and milk are then quickly weighed. The weight of the empty dish subtracted from the last weight is the weight of the charge, and should be about 2 grams.

Evaporating the water.—The dishes containing the milk are now placed in the oven, dried for about four hours, and then placed in the desiccator until cool, when they are weighed. They are then returned to the oven for 30 minutes, after which they are cooled and weighed as before. If there is no loss in weight, or if there is a slight gain in weight during the 30 minutes, it indicates that all the water is driven off, and this last weight minus the weight of the empty dish is the weight of the total solids in the charge taken. This multiplied by 100 and divided by the weight of the charge gives the percentage. If there was a loss in weight during the 30 minutes, the dishes are returned to the oven and dried for another period or until they cease to lose weight.

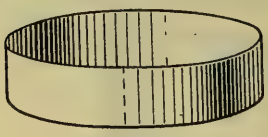

FIG. 28.—Milk dish.

Determination of solids not fat.—The percentage of solids not fat, or serum solids, is found by subtracting the percentage of fat from the percentage of total solids.

DETERMINATION OF SPECIFIC GRAVITY OF MILK.

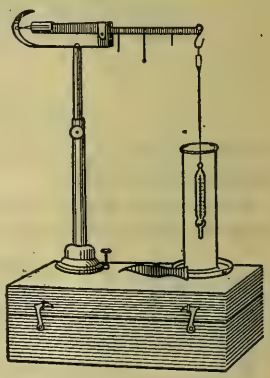

FIG. 29.—Westphal balance.

For exact work the specific gravity of milk is determined by comparing the weight of a volume of milk with that of an equal volume of pure water under controlled-temperature conditions. For inspection work an instrument known as the Westphal balance or the special lactometer described in Bulletin 134 of the Bureau of Animal Industry, United States Department of Agriculture, is sufficiently accurate.

Westphal balance.—This instrument (fig. 29) consists of a pivoted beam graduated on one arm and bearing a plummet or float. The weights in terms of specific gravity represent unity, tenths, hundredths, thousandths, and ten-thousandths. With no weight on the beam it balances when the plummet floats in air. When the unit weight is in position, it balances when the plummet floats in pure water at the proper temperature. When the plummet is submerged in a liquid heavier than water, such as milk, additional weights are required to bring the instrument to equilibrium. The specific gravity is read off directly from the value of the weights and their position on the beam. Detailed directions usually accompany the instrument.

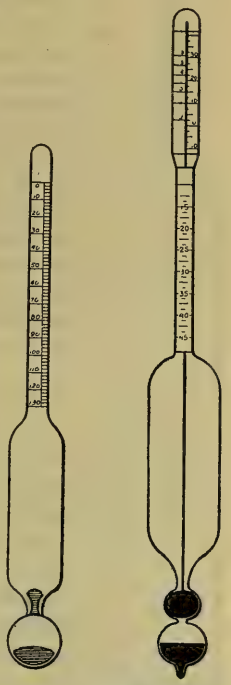

FIG. 30.—Types of ordinary lactometers.

Lactometers.—Most lactometers are not sensitive enough for determining the specific gravity of milk if more than approximate figures are required. The use of either the Westphal balance or the special lactometer, previously mentioned, is advised. If, however, only approximate results are required the ordinary lactometer, of which there are several types on the market, will suffice.

The lactometer (figs. 30 and 31) is used exactly in the same manner as is the hydrometer in testing sulphuric acid, directions for which are given on page 10. Care must be taken that the milk is at the temperature at which the lactometer is standardized and that the lactometer floats freely in the cylinder. The specific gravity of milk can not be taken until the milk is three or four hours old. The point on the scale of the lactometer where the surface of the milk intercepts represents the specific

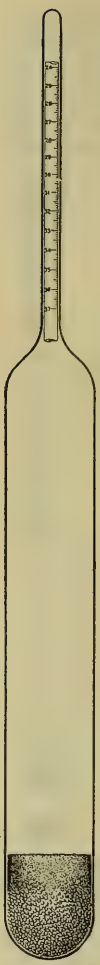

FIG. 31.—Special lactometer described in Bulletin 134, Bureau of Animal Industry, U. S. Department of Agriculture.

gravity which is usually expressed in Quevenne degrees.[1] A slight meniscus will obscure the surface line, and it is necessary to estimate its depth. This will cause no error if it is remembered that the point to be read is at the surface of the milk and not at the top of the meniscus.

A type of lactometer known as the New York board of health lactometer is in somewhat general use. The scale of this instrument does not give the specific gravity directly, but is so arranged that milk having a specific gravity of 1.029 (at 60° F.) will read 100°. As the zero mark is the point to which it will sink when immersed in pure water, 100° on the scale corresponds to 29° on the Quevenne scale. New York board of health lactometer degree may be converted into Quevenne degrees by multiplying by 0.29.

CALCULATING TOTAL SOLIDS BY FORMULA.

When the percentage of fat and the specific gravity of the milk are known and only the closely approximate percentage of total solids is wanted, it should be calculated by the Babcock formula. The following table and directions for using it are taken from Bureau of Animal Industry Bulletin 134:

[1] Quevenne degrees are converted into specific gravity by dividing by 1,000 and then adding 1 to the quotient. This is done at a glance. For example, if the Quevenne reading is 32.5, the specific gravity is 1.0325.

Table for determining total solids in milk from any given specific gravity and percentage of fat.

[Per cent total solids.]

Per-centage of fat.	Lactometer reading at 60° F. (Quevenne degrees).										
	26	27	28	29	30	31	32	33	34	35	36
2.00	8.90	9.15	9.40	9.65	9.90	10.15	10.40	10.66	10.91	11.16	11.41
2.05	8.96	9.21	9.46	9.71	9.96	10.21	10.46	10.72	10.97	11.22	11.47
2.10	9.02	9.27	9.52	9.77	10.02	10.27	10.52	10.78	11.03	11.28	11.53
2.15	9.08	9.33	9.58	9.83	10.08	10.33	10.58	10.84	11.09	11.34	11.59
2.20	9.14	9.39	9.64	9.89	10.14	10.39	10.64	10.90	11.15	11.40	11.65
2.25	9.20	9.45	9.70	9.95	10.20	10.45	10.70	10.96	11.21	11.46	11.71
2.30	9.26	9.51	9.76	10.01	10.26	10.51	10.76	11.02	11.27	11.52	11.77
2.35	9.32	9.57	9.82	10.07	10.32	10.57	10.82	11.08	11.33	11.58	11.83
2.40	9.38	9.63	9.88	10.13	10.38	10.63	10.88	11.14	11.39	11.64	11.89
2.45	9.44	9.69	9.94	10.19	10.44	10.69	10.94	11.20	11.45	11.70	11.95
2.50	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.26	11.51	11.76	12.01
2.55	9.56	9.81	10.06	10.31	10.56	10.81	11.06	11.32	11.57	11.82	12.07
2.60	9.62	9.87	10.12	10.37	10.62	10.87	11.12	11.38	11.63	11.88	12.13
2.65	9.68	9.93	10.18	10.43	10.68	10.93	11.18	11.44	11.69	11.94	12.19
2.70	9.74	9.99	10.24	10.49	10.74	10.99	11.24	11.50	11.75	12.00	12.25
2.75	9.80	10.05	10.30	10.55	10.80	11.05	11.31	11.56	11.81	12.06	12.31
2.80	9.86	10.11	10.36	10.61	10 86	11.11	11.37	11.62	11.87	12.12	12.37
2.85	9.92	10.17	10.42	10.67	10.92	11.17	11.43	11.68	11.93	12.18	12.43
2.90	9.98	10.23	10.48	10.73	10.98	11.23	11.49	11.74	11.99	12.24	12.49
2.95	10.04	10.29	10.54	10.79	11.04	11.30	11.55	11.80	12.05	12.30	12.55
3.00	10.10	10.35	10.60	10.85	11.10	11.36	11.61	11.86	12.11	12.36	12.61
3.05	10.16	10.41	10.66	10.91	11.17	11.42	11.67	11.92	12.17	12.42	12.68
3.10	10.22	10.47	10.72	10.97	11.23	11.48	11.73	11.98	12.23	12.48	12.74
3.15	10.28	10.53	10.78	11.03	11.29	11.54	11.79	12.04	12.29	12.55	12.80
3.20	10.34	10.59	10.84	11.09	11.35	11.60	11.85	12.10	12.35	12.61	12.86
3.25	10.40	10.65	10.90	11.16	11.41	11.66	11.91	12.16	12.42	12.67	12.92
3.30	10.46	10.71	10.96	11.22	11.47	11.72	11.97	12.22	12.48	12.73	12.98
3.35	10.52	10.77	11.03	11.28	11.53	11.78	12.03	12.28	12.54	12.79	13.04
3.40	10.58	10.83	11.09	11.34	11.59	11.84	12.09	12.34	12.60	12.85	13.10
3.45	10.64	10.89	11.15	11.40	11.65	11.90	12.15	12.40	12.66	12.91	13.16
3.50	10.70	10.95	11.21	11.46	11.71	11.96	12.21	12.46	12.72	12.97	13.22
3.55	10.76	11.02	11.27	11.52	11.77	12.02	12.27	12.52	12.78	13.03	13.28
3.60	10.82	11.08	11.33	11.58	11.83	12.08	12.33	12.58	12.84	13.09	13.34
3.65	10.88	11.14	11.39	11.64	11.89	12.14	12.39	12.64	12.90	13.15	13.40
3.70	10.94	11.20	11.45	11.70	11.95	12.20	12.45	12.70	12.96	13.21	13.46
3.75	11.00	11.26	11.51	11.76	12.01	12.26	12.51	12.76	13.02	13.27	13.52
3.80	11.06	11.32	11.57	11.82	12.07	12.32	12.57	12.82	13.08	13.33	13.58
3.85	11.12	11.38	11.63	11.88	12.13	12.38	12.63	12.88	13.14	13.39	13.64
3.90	11.18	11.44	11.69	11.94	12.19	12.44	12.69	12.94	13.20	13.45	13.70
3.95	11.24	11.50	11.75	12.00	12.25	12.50	12.75	13.00	13.26	13.51	13.77
4.00	11.30	11.56	11.81	12.06	12.31	12.56	12.81	13.06	13.32	13.57	13.83
4.05	11.36	11.62	11.87	12.12	12.37	12.62	12.87	13.12	13.38	13.63	13.89
4.10	11.42	11.68	11.93	12.18	12.43	12.68	12.93	13.18	13.44	13.69	13.95
4.15	11.48	11.74	11.99	12.24	12.49	12.74	12.99	13.25	13.50	13.76	14.01
4.20	11.54	11.80	12.05	12.30	12.55	12.80	13.05	13.31	13.56	13.82	14.07
4.25	11.60	11.86	12.11	12.36	12.61	12.86	13.12	13.37	13.62	13.88	14.13
4.30	11.66	11.92	12.17	12.42	12.67	12.92	13.18	13.43	13.68	13.94	14.19
4.35	11.72	11.98	12.23	12.48	12.73	12.98	13.24	13.49	13.74	14.00	14.25
4.40	11.78	12.04	12.29	12.54	12.79	13.04	13.30	13.55	13.80	14.06	14.31
4.45	11.84	12.10	12.35	12.60	12.85	13.10	13.36	13.61	13.86	14 12	14.37

Table for determining total solids in milk from any given specific gravity and percentage of fat—Continued.

[Per cent total solids.]

Per-centage of fat.	Lactometer reading at 60° F. (Quevenne degrees).										
	26	27	28	29	30	31	32	33	34	35	36
4.50	11.90	12.16	12.41	12.66	12.91	13.16	13.42	13.67	13.92	14.18	14.43
4.55	11.97	12.22	12.47	12.72	12.97	13.22	13.48	13.73	13.98	14.24	14.49
4.60	12.03	12.28	12.53	12.78	13.03	13.28	13.54	13.79	14.04	14.30	14.55
4.65	12.09	12.34	12.59	12.84	13.09	13.34	13.60	13.85	14.10	14.36	14.61
4.70	12.15	12.40	12.65	12.90	13.15	13.40	13.66	13.91	14.16	14.42	14.67
4.75	12.21	12.46	12.71	12.96	13.21	13.46	13.72	13.97	14.22	14.48	14.73
4.80	12.27	12.52	12.77	13.02	13.27	13.52	13.78	14.03	14.28	14.54	14.79
4.85	12.33	12.58	12.83	13.08	13.33	13.58	13.84	14.09	14.34	14.60	14.85
4.90	12.39	12.64	12.89	13.14	13.39	13.64	13.90	14.15	14.40	14.66	14.91
4.95	12.45	12.70	12.95	13.20	13.45	13.70	13.96	14.21	14.46	14.72	14.97
5.00	12.51	12.76	13.01	13.26	13.51	13.76	14.02	14.27	14.52	14.78	15.03
5.05	12.57	12.82	13.07	13.32	13.57	13.83	14.08	14.33	14.58	14.84	15.09
5.10	12.63	12.88	13.13	13.38	13.63	13.89	14.14	14.39	14.64	14.90	15.15
5.15	12.69	12.94	13.19	13.44	13.69	13.95	14.20	14.45	14.70	14.96	15.21
5.20	12.75	13.00	13.25	13.50	13.75	14.01	14.26	14.51	14.76	15.02	15.27
5.25	12.81	13.06	13.31	13.56	13.81	14.07	14.32	14.57	14.82	15.08	15.33
5.30	12.87	13.12	13.37	13.62	13.87	14.13	14.38	14.63	14.88	15.14	15.39
5.35	12.93	13.18	13.43	13.68	13.93	14.19	14.44	14.70	14.95	15.20	15.45
5.40	12.99	13.24	13.49	13.74	14.00	14.25	14.50	14.76	15.01	15.26	15.51
5.45	13.05	13.30	13.55	13.80	14.06	14.31	14.56	14.82	15.07	15.32	15.57
5.50	13.11	13.36	13.61	13.86	14.12	14.37	14.62	14.88	15.13	15.38	15.63
5.55	13.17	13.42	13.67	13.93	14.18	14.43	14.69	14.94	15.19	15.44	15.69
5.60	13.23	13.48	13.73	13.99	14.24	14.49	14.75	15.00	15.25	15.50	15.75
5.65	13.29	13.54	13.79	14.05	14.30	14.55	14.81	15.06	15.31	15.56	15.81
5.70	13.35	13.60	13.85	14.11	14.36	14.61	14.87	15.12	15.37	15.62	15.87
5.75	13.41	13.66	13.91	14.17	14.42	14.68	14.93	15.18	15.43	15.68	15.93
5.80	13.47	13.72	13.97	14.23	14.48	14.74	14.99	15.24	15.49	15.74	15.99
5.85	13.53	13.78	14.04	14.29	14.54	14.80	15.05	15.30	15.55	15.80	16.06
5.90	13.59	13.84	14.10	14.35	14.60	14.86	15.11	15.36	15.61	15.86	16.12
5.95	13.65	13.90	14.16	14.41	14.66	14.92	15.17	15.42	15.67	15.92	16.18
6.00	13.71	13.96	14.22	14.47	14.72	14.98	15.23	15.48	15.73	15.98	16.24
6.05	13.77	14.02	14.28	14.53	14.78	15.04	15.29	15.54	15.79	16.04	16.30
6.10	13.83	14.08	14.34	14.59	14.84	15.10	15.35	15.60	15.85	16.10	16.35
6.15	13.89	14.14	14.40	14.65	14.90	15.16	15.41	15.66	15.91	16.16	16.42
6.20	13.95	14.20	14.46	14.71	14.96	15.22	15.47	15.72	15.97	16.22	16.48
6.25	14.01	14.26	14.52	14.77	15.02	15.28	15.53	15.78	16.03	16.28	16.54
6.30	14.07	14.32	14.58	14.83	15.08	15.34	15.59	15.84	16.09	16.34	16.60
6.35	14.13	14.38	14.64	14.90	15.14	15.40	15.65	15.90	16.15	16.40	16.66
6.40	14.19	14.44	14.70	14.96	15.20	15.46	15.71	15.96	16.21	16.46	16.72
6.45	14.25	14.50	14.76	15.02	15.26	15.52	15.77	16.02	16.27	16.52	16.78
6.50	14.31	14.56	14.82	15.08	15.32	15.58	15.83	16.08	16.33	16.58	16.84
6.55	14.37	14.62	14.88	15.14	15.38	15.64	15.89	16.14	16.39	16.64	16.90
6.60	14.43	14.68	14.94	15.20	15.44	15.70	15.95	16.20	16.45	16.70	16.96
6.65	14.49	14.74	15.00	15.26	15.50	15.76	16.01	16.26	16.51	16.76	17.02
6.70	14.55	14.80	15.06	15.32	15.56	15.82	16.07	16.32	16.57	16.82	17.08
6.75	14.61	14.86	15.12	15.38	15.62	15.88	16.13	16.38	16.63	16.88	17.14
6.80	14.67	14.92	15.18	15.44	15.68	15.94	16.19	16.44	16.69	16.94	17.20
6.85	14.73	14.98	15.24	15.50	15.74	16.00	16.25	16.50	16.75	17.00	17.26
6.90	14.79	15.04	15.30	15.56	15.80	16.06	16.31	16.56	16.81	17.06	17.32
6.95	14.85	15.10	15.36	15.62	15.86	16.12	16.37	16.62	16.87	17.12	17.38

Table for determining total solids in milk from any given specific gravity and percentage of fat—Continued.

PROPORTIONAL PARTS.

Lactometer fraction.	Fraction to be added to total solids.	Lactometer fraction.	Fraction to be added to total solids.	Lactometer fraction.	Fraction to be added to total solids.
0.1	0.03	0.4	0.10	0.7	0.18
.2	.05	.5	.13	.8	.20
.3	.08	.6	.15	.9	.23

Directions for using the table.—If the specific gravity as expressed in Quevenne degrees is a whole number, the percentage of total solids is found at the intersection of the vertical column headed by this number with the horizontal column corresponding to the percentage of fat.

If the specific gravity as expressed in Quevenne degrees is a whole number and a decimal, the percentage of total solids corresponding to the whole number is first found, and to this is added the fraction found opposite the tenth under "Proportional Parts." Two examples may suffice for illustration: (1) Fat, 3.8 per cent; specific gravity, 32. Under column headed 32, 12.57 per cent is found corresponding to 3.8 per cent fat. (2) Fat, 3.8 per cent; specific gravity, 32.5. The percentage of total solids corresponding to this percentage of fat and a specific gravity of 32 is 12.57. Under "Proportional Parts" the fraction 0.13 appears opposite 0.5. This added to 12.57 makes 12.70, which is the desired percentage.

An inspection of the table shows that the percentage of total solids increases practically at the rate of 0.25 for each lactometer degree and 1.2 for each per cent of fat. This gives rise to Babcock's simple formula: Total solids= $\frac{1}{4}$ L+1.2 F. (L=lactometer reading in Quevenne degrees and f=percentage of fat.)

To illustrate the use of the formula the following example is given: Fat, 4 per cent; specific gravity, 32. In this case one-quarter of 32 is 8; 1.2 multiplied by 4 is 4.8; 8 plus 4.8 equals 12.8, which represents the percentage of total solids.

This simple formula can be used in cases not provided for in the table.

DETERMINATION OF ACIDITY OF MILK AND CREAM.

Acidity in milk is attributable to two causes, (1) the presence in milk of acid phosphates and perhaps of carbon dioxid, and (2) lactic and other acids produced by the decomposition of the milk sugar by bacterial action. When freshly drawn milk is acid to phenolphthalein, this acidity is from 0.07 per cent to 0.08 per cent and is owing to causes given under (1). Lactic acid is not present in freshly drawn milk; it develops only on standing. Milk is not sour to the taste until it has a total acidity of at least 0.3 per cent.

For convenience the total acidity of milk is usually calculated as lactic acid. The principle upon which the determination of acidity is based is the well-known chemical action of acids upon alkalies. To illustrate, the action of hydrochloric (sometimes called muriatic) acid on a solution of caustic soda may be taken. This acid has a sharp and very sour taste, while caustic-soda solutions have a soapy feel and a peculiar odor, and if sufficiently strong will attack the skin. If the solution of caustic soda is slowly added to the hydrochloric acid, the sour taste will gradually disappear until the exact point of neutrality is reached, when a new substance is produced—sodium chlorid, or common salt, which has neither the acid properties of the one nor the alkaline properties of the other. The sense of taste, however, is not sufficiently sensitive to determine when the exact point of neutrality has been reached. Phenolphthalein is an organic compound, having the property, when in solution, of turning pink with alkalies and remaining colorless with acids. Such a substance is called an indicator because it indicates by a color change when a certain chemical reaction has taken place.

There are several so-called acid tests before the public. The one known as Manns's acidity test is widely used and is conducted as follows:

MANNS'S ACIDITY TEST.

Apparatus required:

One 50 cubic centimeter glass burette graduated to tenths, with stopcock.

One 50 cubic centimeter pipette.

One 250 cubic centimeter beaker, or a white teacup.

One support for burette.

Glass stirring rods.

One-tenth normal solution of caustic soda, each cubic centimeter of which will neutralize 0.009 gram of lactic acid.

An alcoholic solution of phenolphthalein made by dissolving 10 grams in 300 cubic centimeters of 90 per cent alcohol.

One who has not had training in chemistry should not attempt to make the tenth-normal solution of caustic soda, as it can be purchased to better advantage from any chemical supply house.

Conducting the test.—With the pipette 50 cubic centimeters of the milk or cream is measured into the beaker or cup. If the cream is thick, it may be slightly warmed. The burette is filled with the tenth-normal caustic-soda solution so that the lowest part of the meniscus is level with the zero point on the graduations. The solution is now run slowly from the burette into the milk or cream, stirring with a glass rod at the same time. It will be noticed that the alkali at once produces a pink color where it strikes; this, however, disappears on stirring. As more and more of the alkali is added, it will be noticed that the pink color is slower in disappearing until finally it becomes permanent for a time. Toward the end, the alkali should be added drop by drop and the very first appearance of a permanent faint pink is the signal that the neutral point has been reached. This color, on account of absorption of carbon dioxid from the air, will disappear after standing a short time. The number of cubic centimeters of alkali used can be learned by referring to the burette, remembering that the reading is taken from the lowest point of the meniscus.

The percentage of acidity is calculated by multiplying the number of cubic centimeters of alkali solution used by 0.009 and dividing by the number of cubic centimeters of milk or cream taken, the quotient being multiplied by 100. Thus:

$$\text{Percentage of acidity} = \frac{\text{c. c. alkali} \times .009}{\text{c. c. sample tested}} \times 100.$$

If 50 cubic centimeters of the sample required 10 cubic centimeters of the alkali to neutralize, the percentage of acidity would be

$$\frac{10 \times .009}{50} \times 100, \text{ or } 0.18 \text{ per cent.}$$

THE DETECTION OF PRESERVATIVES.

The preservatives usually met with are formaldehyde, borax, and boric acid, and these are not difficult to detect if care is used in conducting the tests. Until one is thoroughly familiar with the tests it is a good plan to run three samples together, one being the suspected sample, one which is known to contain the preservative looked for, and one known to be free from that preservative.

Formaldehyde.—There are two well-known tests for detecting formaldehyde, one known as the Hehner test and the other as the Leach test.

In the Hehner test, about 5 cubic centimeters of the milk is placed in a 6 by ½ inch test tube, and then about the same quantity of concentrated sulphuric acid to which a trace of ferric chlorid has been added. The acid is allowed to run down the side of the test tube so as not to mix with the milk. In a few minutes the presence of formaldehyde will be indicated by a violent coloration at the juncture of the milk and the acid. This must not be confused with the charring of the milk by the acid. A modification which avoids this charring is in use in the dairy laboratory of the Bureau of Chemistry, United States Department of Agriculture, the only difference being that the sulphuric acid used is diluted with water until it has a specific gravity of 1.8.

The Leach test, which is the more delicate test of the two, is conducted as follows: To 10 cubic centimeters of

the milk in a white teacup, 10 cubic centimeters of concentrated hydrochloric acid (specific gravity 1.2) containing one part by volume of a 10 per cent ferric-chlorid solution per 500 parts is added and the mixture brought slowly to a boil over a Bunsen burner. Formaldehyde is indicated by a violent coloration varying in intensity with the amount present.

Borax and boric acid.—Twenty-five cubic centimeters of the milk is treated with limewater until a piece of red litmus paper when immersed in it turns distinctly blue. The mixture is evaporated to dryness in a small platinum or porcelain dish and then burned to an ash. A few drops (not too much) of hydrochloric acid are added to the ash, and then a few drops of water. A strip of turmeric paper is then dipped in the solution. When the turmeric paper becomes dry, it will be of a cherry-red color if borax or boric acid is present. The test is still more certain if, when the paper is moistened with an alkaline solution, it turns a dark-olive color.

A test for the detection of borax or boric acid which is in use in the dairy laboratory of the Bureau of Chemistry, United States Department of Agriculture, and by which the ignition of the milk is avoided, is conducted as follows: Ten cubic centimeters of the milk is mixed with 5 cubic centimeters of hydrochloric acid in a white cup. A strip of turmeric paper about 3 inches long is suspended in the mixture so that at least 2 inches of the dry strip remain out of the liquid. The dry portion of the paper will gradually become moist by capillarity, and if borax or boric acid is present the paper will take on a reddish-brown tint. If only a trace of the preservative is present, several hours may be required for this color to develop. A drop of ammonia water on the red portion will produce an olive-green color, which becomes lighter, and finally disappears as the ammonia evaporates.

CHEMICALS AND APPARATUS USED IN THE CHEMICAL ANAYLSIS OF MILK AND CREAM.

Chemicals:

- Ammonia water.
- Borax or boric acid.
- Caustic soda.
- Caustic soda, tenth-normal solution.
- Caustic potash.
- Corrosive sublimate.
- Ether.
- Ferric chlorid.
- Formaldehyde.
- Hydrochloric acid, concentrated.
- Potassium bichromate.
- Phenolphthalein.
- Sulphuric acid, commercial.
- Sulphuric acid, pure concentrated.
- Litmus paper, blue.
- Litmus paper, red.
- Turmeric paper.

Apparatus:

- Balance, analytical, with weights.
- Balance, cream test.
- Balance, Westphal.
- Babcock tester.
- Beakers, 250 c. c. and 500 c. c.
- Burner, Bunsen.
- Burette, 50 c. c., graduated to tenths, with stopcock.

Apparatus—Continued.

- Cylinder, for acid hydrometer.
- Cylinder, for lactometer.
- Condenser for oven.
- Desiccator.
- Dishes, milk.
- Dishes, evaporating, either porcelain or platinum.
- Drying oven, double-walled.
- Forceps.
- Hydrometer, acid.
- Jars, sample.
- Jars, stoneware.
- Lactometer.
- Measure, acid, 17.5 c. c.
- Pipette, 17.6 c. c.
- Pipette, 50 c. c.
- Stirring rods, glass.
- Support for burette.
- Test bottles, Babcock, for milk.
- Test bottles, Babcock, for cream.
- Tongs, crucible.
- Test tubes, 6 by inch.

Comparison of metric and customary weights and measures.

Customary weights and measures.	Equivalents in metric system.	Metric weights and measures.	Equivalents in customary system.
1 inch	2.54 centimeters.	1 meter	39.37 inches.
1 foot	0.3048 meter.	1 meter	1.0936 yards.
1 square inch	6.452 square centimeters.	1 square centimeter.	0.155 square inch.
1 square foot	9.29 square decimeters.	1 square meter.	10.764 square feet.
1 cubic inch	16.387 cubic centimeters.	1 cubic centimeter.	0.061 cubic inch.
1 cubic foot	0.0283 cubic meter.	1 cubic centimeter.	0.0338 fluid ounce.
1 fluid ounce	29.57 cubic centimeters.	1 cubic decimeter.	61.023 cubic inches.
1 quart	0.9464 liter.	1 liter	1.0567 quarts.
1 gallon	3.7854 liters.	1 dekaliter	2.6417 gallons.
1 grain	64.8 milligrams.	1 gram	15.43 grains.
1 ounce (av.)	28.35 grams.	1 gram	0.035274 ounce.
1 pound (av.)	0.4536 kilogram.	1 kilogram	2.2046 pounds (av.)

Comparison of Fahrenheit and Centigrade thermometer scales.

Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.
°	°	°	°	°	°
212	100.00	183	83.89	154	67.78
211	99.44	182	83.33	153	67.22
210	98.89	181	82.78	152	66.67
209	98.33	180	82.22	151	66.11
208	97.78	179	81.67	150	65.55
207	97.22	178	81.11	149	65.00
206	96.67	177	80.55	148	64.44
205	96.11	176	80.00	147	63.89
204	95.55	175	79.44	146	63.33
203	95.00	174	78.89	145	62.78
202	94.44	173	78.33	144	62.22
201	93.89	172	77.78	143	61.67
200	93.33	171	77.22	142	61.11
199	92.78	170	76.67	141	60.55
198	92.22	169	76.11	140	60.00
197	91.67	168	75.55	139	59.44
196	91.11	167	75.00	138	58.89
195	90.55	166	74.44	137	58.33
194	90.00	165	73.89	136	57.78
193	89.44	164	72.33	135	57.22
192	88.89	163	72.78	134	56.67
191	88.33	162	71.22	133	56.11
190	87.78	161	71.67	132	55.55
189	87.22	160	71.11	131	55.00
188	86.67	159	70.55	130	54.44
187	86.11	158	70.00	129	53.89
186	85.55	157	69.44	128	53.33
185	85.00	156	68.89	127	52.78
184	84.44	155	68.33	126	52.22

Fahrenheit and Centigrade thermometer scales—Continued.

Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.
°	°	°	°	°	°
125	51.67	82	27.78	39	3.89
124	51.11	81	27.22	38	3.33
123	50.55	80	26.67	37	2.78
122	50.00	79	26.11	36	2.22
121	49.44	78	25.55	35	1.67
120	48.89	77	25.00	34	1.11
119	48.33	76	24.44	33	0.55
118	47.78	75	23.89	32	0.00
117	47.22	74	23.33	31	− 0.55
116	46.67	73	22.78	30	− 1.11
115	46.11	72	22.22	29	− 1.67
114	45.55	71	21.67	28	− 2.22
113	45.00	70	21.11	27	− 2.78
112	44.44	69	20.55	26	− 3.33
111	43.89	68	20.00	25	− 3.89
110	43.33	67	19.44	24	− 4.44
109	42.78	66	18.89	23	− 5.00
108	42.22	65	18.33	22	− 5.55
107	41.67	64	17.78	21	− 6.11
106	41.11	63	17.22	20	− 6.67
105	40.55	62	16.67	19	− 7.22
104	40.00	61	16.11	18	− 7.78
103	39.44	60	15.55	17	− 8.33
102	38.89	59	15.00	16	− 8.89
101	38.33	58	14.44	15	− 9.44
100	37.78	57	13.89	14	−10.00
99	37.22	56	13.33	13	−10.55
98	36.67	55	12.78	12	−11.11
97	36.11	54	12.22	11	−11.67
96	35.55	53	11.67	10	−12.22
95	35.00	52	11.11	9	−12.78
94	34.44	51	10.55	8	−13.33
93	33.89	50	10.00	7	−13.89
92	33.33	49	9.44	6	−14.44
91	32.78	48	8.89	5	−15.00
90	32.22	47	8.33	4	−15.55
89	31.67	46	7.78	3	−16.11
88	31.11	45	7.22	2	−16.67
87	30.55	44	6.67	1	−17.22
86	30.00	43	6.11	0	−17.78
85	29.44	42	5.55	− 1	−18.33
84	28.89	41	5.00	− 2	−18.89
83	28.33	40	4.44	− 3	−19.44

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